Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 3 (2015) 1580 – 1586

Procedia MANUFACTURING

6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

Integrative physical and cognitive training development to better meet airmen mission requirements

Molly V. Fischer[a], Jason Stone[a], Teresa D. Hawkes[b], Edward Eveland[c], Adam J. Strang[c]

[a] *Oak Ridge Institute of Science & Education, Wright-Patterson AFB, Dayton, 45433, United States*
[b] *National Research Council, Wright-Patterson AFB, Dayton, 45433, United States*
[c] *Air Force Research Laboratory, 711th Human Performance Wing, RHC, Wright-Patterson AFB, Dayton, 45433, United States*

Abstract

In today's high-intensity Air Force (AF) operations, Airmen are often required to perform demanding cognitive and physical tasks simultaneously, or in close concert (e.g., AF Explosive Ordinance Disposal) [1]. However, most AF training programs [e.g., squadron physical training (PT)] do not account for these operational requirements, and thus may not optimally instill the combined skills that are required of Airmen to perform their jobs efficiently and effectively. To address this issue, we have initiated a research and development program that seeks to create and validate specific exercises, routines, and comprehensive workout programs that integrate cognitive ('brain') training with contemporary PT exercises (e.g., performing body squats while concurrently tracking incoming information to improve lower body strength and working memory capacity). This initiative is inspired by, 1) findings indicating a positive relationship between specific modes of physical exercise (e.g., agility drills and Tai Chi) and cognitive performance (e.g., attention and working memory) [2, 3], 2) growing research interest in the effects and application of "brain training" [4], and 3) the AF's stated goal of developing personalized health and human performance technologies [5]. To accomplish this, we are currently developing training exercises and routines based on knowledge of operator physical and cognitive requirements obtained from quantitative and qualitative reports, surveys and interviews. These requirements are then distilled and paired in creative and practical ways to generate exercises and workout routines that can be instantiated effectively and efficiently into daily PT sessions performed in garrison at base fitness centers, at home, or down-range. Here, we share some of the exercises and routines we have developed, describe the philosophy and theoretical framework of our initiative, and provide a glimpse into future research in this area.

Keywords: U.S. Air Force; Physical training; Cognition; Fitness; Program development; Military

doi:10.1016/j.promfg.2015.07.445

Fig. 1. A United States Air Force Combat Medic preparing to go out on patrol.

1. Introduction

United States Air Force (AF) operations increasingly require that specialized technical skills be performed by operators placed under high levels of physical and mental stress. For example, AF medics, who can embed within units of any military branch, are often sent on convoys and patrols where they are faced with difficult challenges, such as performing triage, making rapid decisions about medical care in austere conditions, and evacuating the wounded. They do all this while wearing full combat gear and carrying a host of medical supplies in a rucksack (total gear weight for an AF medic can be upwards of 100 lbs.; Fig. 1). For these Airmen, and many others, developing and maintaining states of physical and cognitive readiness pose a growing challenge to the AF.

Presently, the AF provides extraordinary job-skills training for a number of specialized military occupations through established training pipelines that often include classroom teaching, test certifications, high-fidelity simulations and live training exercises. However, from both fiscal and manning perspectives, training pipelines are expensive and time-consuming, and thus typically take place in concentrated bouts. Conversely, the maintenance of day-to-day occupational readiness is accomplished through squadron physical training (PT) [6].

The type and frequency of PT performed by Airmen can vary due to the fact that PT development and implementation in the AF is at the discretion of local unit commanders and physical training leads (PTLs), i.e., Airmen who are given the duty of preparing PT for their units or squadrons [6]. However, recent unpublished data lately obtained using semi-structured interviews ($N \sim 45$), surveys, and field observations indicates that current AF PT activities tend to include mostly traditional exercises and team sports, such as steady-state running, calisthenics, resistance training, soccer, and volleyball.

Interestingly, these types of PT activities may have benefit for maintaining rudimentary, but possibly not optimal, levels of physical and cognitive readiness. With specific reference to the latter, this speculation is supported by evidence showing that acute, and regularly performed, bouts of physical exercise can result in the enhancement of some cognitive functions, such as information processing speed [7, 8], executive function [9], and continuous memory [3]. We posit that these effects might be enhanced in Airmen if the physical exercises being performed better replicated AF operational demands. This speculation is based on a theoretical extension of research supporting the efficacy of ‘brain’ training exercises for improving specific cognitive functions (e.g., executive function [4]), accompanied with research indicating that specific types of exercise, specifically those that require heightened concentration and/or the performance of complex motor skills such as Tai Chi [2] and agility drills [3], tend to be more effective for eliciting short- and long-term improvements in cognitive function. In particular, these latter findings hint that PT exercise requiring an explicit focus on mind-body interactions and/or the juggling of multiple performance goals (e.g., maintaining balance while building speed and explosive power in an agility ladder exercise), are more effective for eliciting improved cognitive function. Notably, many of the occupational tasks performed by today’s AF operators require complex motor skills (e.g., flight line operators performing manual

inspection of a jet engine; Figure 2), and we suspect that performing exercises that specifically facilitate those skills in concert with operationally-relevant cognitive exercise when appropriate, may enhance the natural interaction between physical fitness and cognitive function and ultimately lead to improved job performance and readiness. Currently, we are developing a series of controlled research studies to examine this hypothesis. However, in this manuscript our goal is to layout our research and development (R&D) process for creating integrated physical and cognitive exercises, provide detailed descriptions and rationale for a few of the specific exercises we have created, and lend a prospective glimpse into future research in this area.

2. Overview of our R&D process

The primary objectives for the R&D process is to create exercises that are, 1) operationally relevant, 2) effective for improving Airmen job performance and readiness, and 3) are simple and safe to perform in a majority of AF PT environments (e.g., base fitness centers, outdoor sport fields, etc.). The first step toward meeting these goals is to obtain information about the physical and cognitive demands of specific AF occupations, as well as the current PT activities performed by Airmen in various settings. This is accomplished using semi-structured interviews, field observations (of both job tasks and PT activities), and the careful break-down of the latest AF Occupational Analysis Reports (OAR) [10]. This three-pronged approach ensures that we are able to obtain a holistic and nuanced understanding of AF occupational demands and PT activities that might not be fully captured by using any one of these approaches alone.

Next, the information we obtain from the interviews is analyzed using qualitative methods, e.g., content analysis, to provide summaries of emergent thematic outcomes [11]. These results are then triangulated with the AF OAR results and used by our research staff, which is comprised of PhDs in Exercise Physiology, Cognitive and Sport Psychology, Certified Athletic Trainers, and Active Duty Airmen, to guide the creation of PT exercises that integrate physical and cognitive exercises.

Finally, these integrated exercises are validated in two ways. First, they are submitted to subjective evaluation by cohorts of Airmen for their perceived usability and efficacy. Second, these exercises are implemented into laboratory exercise intervention experiments where their effectiveness for producing the desired performance results are compared to other forms of exercise. At this time, it is important to report that we are still in the process of formalizing the evaluation process that will be used by our Airmen and that initial intervention studies are underway, but have not been completed. Because of this, the exercises we describe next reflect those generated following the completion of the first two stages of our R&D process.

3. Examples of integrated physical and cognitive exercises

3.1. Tracking Squats

Working memory, which is described as a temporary holding and processing system for combining new and stored information [12], is a critical cognitive function for correctly perceiving and making judgments about a current contextual state. Because of this, high levels of working memory are generally important for all AF operations, but particularly those in occupations that require complex and rapid decision-making (e.g., Special Operations) [13]. In addition, working memory is known to be a particularly powerful contributor to fluid intelligence [14, 15].

In controlled research studies, one of the most common ways to evaluate (and train) working memory is through the digit-span task [16, 17]. In this task, participants are presented with a series of digits (e.g., '2, 5, 4, 7') that they must immediately repeat back. If they are successful, they are then given a longer list (e.g., '9, 6, 3, 2, 0') to track and recall. The length of the longest list a person can remember is that person's digit span and serves as an indicator of working memory capacity.

In Tracking Squats, we combine the basic elements of the digit span with the execution of an air squat, the latter of which is a simple, common and effective PT exercise for improving low body strength and balance (which are

Fig. 2. An airman demonstrating Tracking Squats.

important physical attributes for a majority of our Airmen). To perform the exercise, 6 rows of 8 numbered playing cards are placed on the ground (Fig. 2). Then, an Airman must squat to pick-up the playing-cards in succession, immediately recalling the number order of the cards following the completion of each row. Performance on the exercise can be scored according to recall accuracy, time to completion, and/or subjective evaluation of squat form.

3.2. Anagram Planks

An anagram refers to the rearrangement of letters or words (e.g., ‘F, A, C, E, I, R, O, A, R’) to produce new words or phrases (e.g., ‘AIR FORCE’) [18]. In previous research, anagrams have been used as indicators of both cognitive ‘flexibility’ [18, 19] and implicit memory (i.e., a cognitive function that aids performance of a task without conscious awareness of previous experience with the same, or similar, task) [20], both of which promote adaptive problem-solving, a critical skills for many AF operations from cyber defense to piloting.

In Anagram Planks, performing a variant of anagrams is paired with a dynamic plank exercise that requires a combination of core strength and balance. To perform this exercise, 8 to 12 notes cards with individual letters written on them are placed in a semi-circle within arms’ reach of the participant. For example, see Fig. 3. An Airman is then asked to hold the plank position while reaching out with one hand to touch letters that create 4-letter words from the available letter set. The objective is to create as many unique 4-letter words as possible in one minute. A potential modification of this exercise is to ask the Airman to create only words related to a specific category (e.g., types of AF aircraft) that is relevant to their occupation, or to create words comprise of more, or fewer, letters. Performance on the exercise can be scored by the number of unique words created in the allotted time and/or subjective scoring of their plank position form.

a b

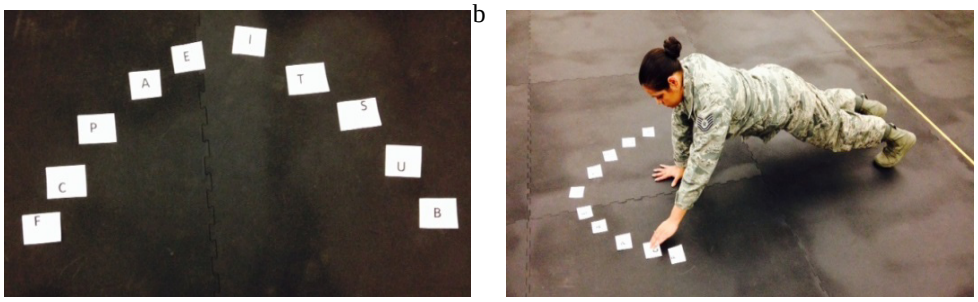

Fig. 3. (a) An example letter set arrangement for “Anagram Planks”; (b) an Airman demonstrating the exercise.

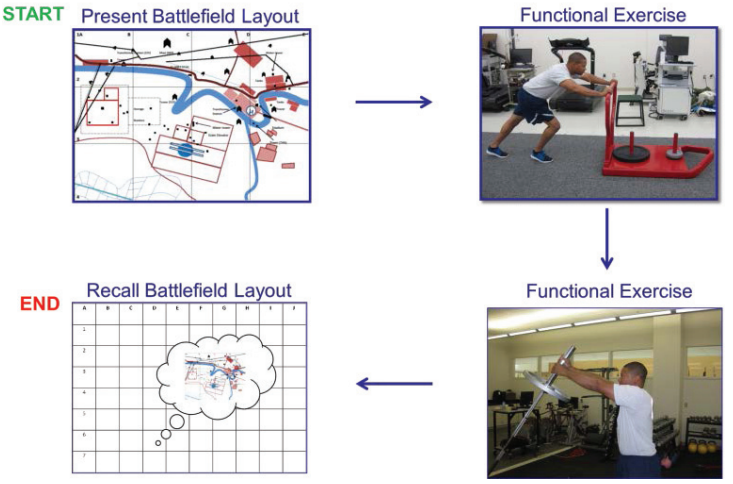

Fig. 4. An abbreviated example of the "Hold That Intel" exercise embedded within a functional exercise circuit.

3.3. Hold That Intel

A number of the AF air and ground-based operator [e.g., Combat Controller, Joint Terminal Attack Controller (JTAC), and Air Battle Managers (ABM)] face situations in which they are required to recall details from a previously reviewed operations order. These details often pertain to spatial information, such as casualty collection sites, vantage points, suspected enemy target locations, and flight paths. With specific reference to ground-based operations, an Airman may need to quickly recall these details immediately following, or while simultaneously engaged in, a physically stressful tasks. The purpose of "Hold That Intel" is to improve Airmen's memory recall in such circumstances.

To perform the exercise, an Airman views and studies a geo-spatial map for a time period of between 10 to 30 seconds. For example, see Fig. 4. The map is typically a low- to mid-fidelity 2D representation that contains the type information, based on their occupation, which they may encounter during a mission. The Airman then completes a functional exercise circuit lasting for 5 to 60 minutes, where upon completion the Airman is asked recall the location of important map feature locations on an unmarked grid. Performance is scored according to the accuracy of the recall (e.g., correct number of features reported and/or root mean square error distance from the actual feature location) and/or their physical performance on the exercise circuit (e.g., number of exercises completed).

3.4. Safest Route Out

Many of our Airmen are faced with circumstances in which with they must rapidly assess the state of situation, make a prediction about future events, and execute a plan. For example, a field medic may need to quickly diagnosis the injury of a fallen soldier, perform triage under hostile conditions, determine the best mode (e.g., drag or carry) and path for safe evacuation, and execute that plan while monitoring for new constraints that might necessitate adaptations. Such circumstances require high levels of rapid pattern recognition, problem-solving and decision making.

In Safest Route Out, we try to promote these skills within the context of a speed and agility running exercise. To perform this exercise we use the Fitlight Trainer ®, a wireless reaction system comprised of eight LED lights controlled by a computer tablet. In the current instantiation (Fig. 5), the lights are affixed at approximately hip height to sturdy surfaces in a semi-circle, though other configurations are likely suitable. At the onset of the exercise, an Airmen stands in the center of the semi-circle while eight red, yellow, and blue lights illuminate simultaneously in a random order. The goal for the Airman is to examine the pattern, determine the most efficient

a b

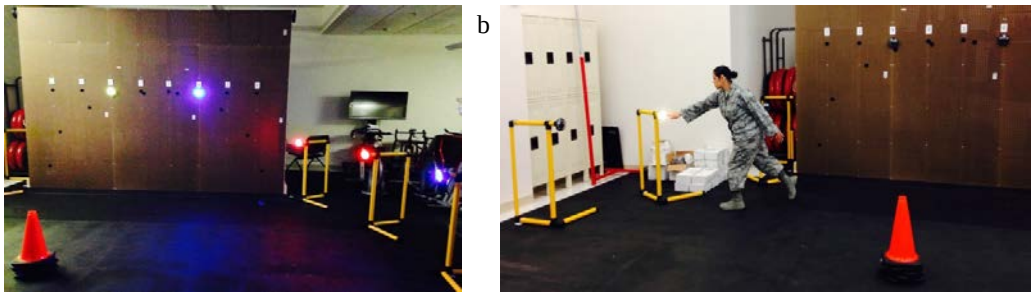

Fig. 5. (a) An example layout for "Safest Route Out"; (b) an Airman forming the exercise.

route for touching and turning off all the lights, and then execute that plan, with the only rule being that the Airman must turn all of the lights off in one color group before moving on to another. This makes the decision of which group of lights to turn off in which order complex, since the most efficient route pattern can involve switch-backs and turnarounds. For example, an Airmen may decide that the most efficient and quickest plan is to turn off all the red lights first, then all the yellow, and finally all the blue. The execution of this strategy might involve a complex zig-zag and/or back-and-forth running path. Once all lights are turned off, a new pattern is immediately illuminated. The full exercise includes three different pattern iterations-using the same color set. Performance on the exercise is evaluated by time-to-completion.

4. The next steps

In this paper we provided an overview of a novel research initiative to develop exercises that better match the multi-modal demands of current AF operations through the integration of physical and cognitive exercises. In addition, we outlined our R&D process and gave detailed descriptions of a few of the exercise we have created. Our next steps are to validate the utility and efficacy of these, and other, exercises of this type through subjective evaluation by Airmen and objective experimentation, as outlined earlier. In addition, we are also focused on developing safe and effective methods for these individual exercises to be placed into daily exercise routines (e.g., as part of a total body exercise circuit) and comprehensive fitness programs that can be used in realistic training settings. Finally, we are considering various options for providing Airmen access to these exercises (e.g., mobile smart phone application), as well as the equipment (e.g., Fitlight Trainer ®) required to perform them. Overall, we believe that the developmental work and approach shown here provides a solid foundation for meeting the goal of developing exercises that will improve occupational job performance and the day-to-day readiness of our Airmen in the 21st century.

References

[1] Lang J. Thomas J. Bliese P. Adler A. Job demands and job performance: The mediating effect of psychological and physical strain and the moderating effect of role clarity. J Occup Health Psychol, 2007; 12, 116.

[2] Hawkes T. Manselle W. Woollacott M. Cross-sectional comparison of executive attention function in normally aging long-term T'ai Chi, meditation, and aerobic fitness practitioners versus sedentary adults. J Altern Complement Med, 20(3), 2013; 178-184.

[3] Lennemann L. Sidrow K. Johnson E. Harrison C. Vojta C. Thomas W. The influence of agility training on physiological and cognitive performance. J Strength Cond Res, 27(12), 2013; 3300-3309.

[4] Nouchi R. Taki Y. Takeuchi H. Hashizume H. Nozawa T. Kambara T. Sekiguchi A. Miyauchi C. Kotozaki Y. Nouchi H. Kawashima R. Brain training game boosts executive functions, working memory and processing speed in the young adults: A randomized controlled trial. PLoS ONE, 2013; 8: 1-13.

[5] Stone M. Human system technologies strategic vectors. Presentation: 15th Annual Science & Technology Engineering Technology/Defense Tech Exposition.

[6] U.S. Air Force. Air Force instruction 36-2905: Personnel fitness program. Department of the Air Force, 2010.

[7] Perry C. Sheik-Nainar M. Segall N. Ma R. Kaber D. Effects of physical workload on cognitive task performance and situation awareness. Theor Issues Ergonomics Sci. 2006;1-19.
[8] Tomporowski P. Effects of acute bouts of exercise on cognition. Acta Psychol (Amst), 2003; 112: 297-324.
[9] Hansen A. Johnsen B. Sollers III J. Stenvik K. Thayer J. (2004). Heart rate variability and its relation to prefrontal cognitive function: the effects of training and detraining. Eur J Appl Physiol 2004; 93: 263-272.
[10] U.S. Air Force. Occupational assessment records. Randolph, TX: Headquarters Air Education & Training Command, 2012.
[11] Patton M. Qualitative research and evaluation methods, 3rd Eds. Thousand Oaks, CA:Sage, 2002.
[12] Baddeley A. Hitch G. Working memory. Psychol Learn and Motiv, 8, 47-89, 1974.
[13] Militello L. Branlat M. Lopez C. Walker K. Finomore V. Ritter J. Bean R. David M. Decision support for pararescue. Proceedings of the 11th International Decision Making Conference, 2013; 73-82.
[14] Fry A. Hale S. Processing speed, working memory, and fluid intelligence: Evidence for a developmental cascade. Psychol Sci 1996; 7: 237-241.
[15] Jaeggi S. Buschkuel M. Jonides J. Perrig W. Improving fluid intelligence with training on working memory. PNAS, 2008; 105: 6829-6833.
[16] Groth-Marnt G. Baker S. Digit span as a measure of everyday attention: A study of ecological validity. Percept Mot Skills 2003; 97: 1209-1218.
[17] Naveh-Benjamin M. Ayres T. Digit span, reading rate, and linguistic relativity. Q J Experimental Psychol, 1986; 38A: 213-225.
[18] Beversdorf D. Hughes J. Steinberg B. Lewis L. Heilman, K. Noradrenergic modulation of cognitive flexibility in problem solving. Neuroreport 1999; 10: 2763-2767.
[19] Walker M. Liston C. Hobson J. Stickgold, R. Cognitive flexibility across the sleep–wake cycle: REM-sleep enhancement of anagram problem solving. Cogn Brain Res 2002; 14: 317-324.
[20] Srinivas K. Roediger, H. Classifying implicit memory tests: Category association and anagram solution. J Mem Lang 1990; 29: 389-412.